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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN THE PATENT APPLICATION OF:

JOEL C. VANDERZEE, MICHAEL W. MURRY, RICHARD L. VOGEL AND MATTHEW A. SHEPECK

U.S. SERIAL NO: 09/976,194 GROUP: 2857

FILED: OCTOBER 11, 2001 EXAMINER: JEFFREY R. WEST

FOR: DETERMINATION AND APPLICATIONS OF THREE-PHASE POWER FACTOR

La Crosse, Wisconsin
October 27, 2006

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10/27/6 William O'Driscoll
Date William O'Driscoll

APPEAL BRIEF

Mail Stop Appeal Brief - Patents

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Dear Sir:

Table of Contents

		Page
I.	Real Party in Interest	5
II.	Related Appeals and Interferences	6
III.	Status of Claims	7
IV.	Status of Amendments	8
V.	Summary of Claimed Subject Matter	9
VI.	Grounds of Rejection to be Reviewed on Appeal	20
VII.	Argument	22

A. Claims 1 and 20 are Novel and Patentable in View of U.S. Patent 5,521,482 to Lang et al.

1. U.S. Patent 5,521,482 to Lang et al. Does Not Disclose Sampling Voltage Levels and Current Levels to Form a Set of Voltage and Current Levels

B. Claims 2 and 20 are Novel and Patentable in View of U.S. Patent 5,521,482 to Lang et al.

1. Claims 2 and 21 Stand Rejected Under 35 U.S.C. Section 102 in View of Lang et al.
2. Lang et al. Makes No Disclosures Regarding Simultaneous Sampling
3. Lang et al. Requires Phase Demodulation
4. Lang et al. Consistently Makes Its Disclosures "As a Function of Time"
5. Lang et al.'s Disclosures are in Terms of RMS

C. Claims 6, 7, 11, 12, 25, 26, 30 and 31 are Novel and Patentable in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,673,196 to Hoffman et al.

1. These Claims are Conceded to be Novel and Patentable in View of Lang et al.
2. No Reason is Provided to Combine Lang et al. with Hoffman et al.

D. Claims 13, 14, 16-19, 32, 33 and 35-38 are Novel and Patentable in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,176 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.

1. These Claims are Conceded to be Novel and Patentable in view of the Combination of Lang et al. and Hoffman et al.
2. A Person of Ordinary Skill in the Art Would Not Combine Kurszewski et al. with Lang et al. and Hoffman et al.
3. There is No Reason to Make the Proposed Combination

E. Claims 17 and 36 are Novel and Patentable in view of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al. and U.S. Patent 5,434,738 to Kurszewski et al.
   1. Lang et al. Does Not Check to Determine if Each of the Determined Consecutive Numbers of Most Recent Values are Less Than or Equal to Zero
   2. Neither Hoffman et al. Nor Kurszewski et al. Remedy the Deficiencies of Lang et al.
   3. There is No Suggestion in the References to Make the Proposed Combination or to Modify the Combination to Reach the Claimed Invention

F. Claims 13, 16, 32 and 35 are Independently Novel and Patentable in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.
   1. The References Do Not Disclose the Concept of Generating a Set or Plurality of Instantaneous Three-Phase Power Factor Data Values
   2. These References Provide No Reason to Make or Modify the Proposed Combination

G. Claims 18 and 37 are Independently Novel and Patentable in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.

H. Claims 39 and 41 are Independently Novel and Patentable in View of U.S. Patent 5,521,482 to Lang et al.
   1. The Cited References Do Not Disclose Determining a Set of Currents and a Set of Voltages Respectively Associated with Three Motor Phases

2. The Cited References Do Not Disclose Calculating Current Phasors and Voltage Phasors from the Set of Currents and the Set of Voltages
3. Use of Phasors as Claimed Does Not Disclose to Calculate an Instantaneous Power Factor
4. There is No Reason to Make the Proposed Combination Nor to Modify the Proposed Combination if Made

I. Claims 40 and 42 are Independently Novel and Patentable in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,229,713 to Bullock et al.
1. Claims 40 and 42 Require an Average of Instantaneous

J. Summary

VIII. Claims Appendix 33

IX. Evidence Appendix 42

A. Record of Evidence Entered by Examiner
B. Specification
C. Drawings
D. U.S. Patent 5,521,482 to Lang et al.
E. U.S. Patent 5,673,196 to Hoffman et al.
F. U.S. Patent 5,434,738 to Kurszewski et al.
G. U.S. Patent 5,229,713 to Bullock et al.

I. Real Party in Interest

The Real Party in Interest is American Standard Inc. (ASI), the assignee of the present application, its parent, American Standard Companies (ASC) and ASC's wholly owned subsidiary American Standard International (ASII).

II. Related Appeals and Interferences

There are no other Appeals or Interferences which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending Appeal which are known to appellant, appellant's legal representative or assignee.

III. Status of Claims

Claims 1-14, 16-33 and 35-42 are pending in this application.

Claims 1-5, 8-10, 20-24, 27-29, 39 and 41 stand rejected under 35 U.S.C. Section 102(b) in view of U.S. Patent 5,521,482 to Lang et al.

Claims 6, 7, 11, 12, 25, 26, 30 and 31 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,673,196 to Hoffman et al.

Claims 13, 14, 16-19, 32, 33 and 35-38 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al., U.S. Patent 5,673,196 to Hoffman et al. and U.S. Patent 5,434,738 to Kurszewski et al.

Claims 40 and 42 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,229,713 to Bullock et al.

Claims 15 and 34 are canceled.

The rejection of all rejected claims is being appealed.

IV. Status of Amendments

There are no unentered amendments.

V. Summary of Claimed Subject Matter

The invention is directed to determining three-phase power factor in a three-phase power system 10 under load and using this three-phase power factor to protect the system 10 from damage caused by such phenomena as momentary power loss conditions (see numbered paragraph 1).

To determine a value of three-phase power factor, the positive and negative levels of voltages and currents are measured from the source lines 30, 40 and 50 by the processor 80, maintaining the positive and negative signs of the measured levels. The measurements may be taken in various combinations of phase and/or voltage levels and current levels such as

first combination:	Vab, Vbc, Vca, Ia, Ib, Ic
second combination:	Va, Vb, Vc, Iab, Ibc, Ica
third combination:	Vab, Vbc, Vca, Iab, Ibc, Ica
fourth combination:	Va, Vb, Vc, Ia, Ib, Ic(see numbered paragraph 34)

Where a, b and c refer to the source lines 30, 40 and 50 respectively. The three voltage levels and the three current levels are sampled and digitized by the processor 80 and are used to calculate the values of a voltage phaser and the values of a current phaser. The values of the real components D_R and I_R and the values of the imaginary components V_i and I_i of the phasors are given by the equation

If Vab, Vbc, and Vca are used:
$Vr=3^{0.5}*0.5*Vbc$ and $Vi=0.5*(Vab-Vca)$
If Va, Vb, and Vc are used:
$Vr= 3^{0.5}*0.5*(Vb-Vc)$ and $Vi=Va-0.5*(Vb+Vc)$
If Ia, Ib, and Ic are used :
$Ir=3^{0.5}*(Ib-Ic)/3$ and $Ii=Ia$
If Iab, Ibc, and Ica are used:
$Ir=3^{0.5}*(2*Ibc-Ica-Iab)/3$and $Ii=Iab-Ica$ (see numbered paragraphs 36-40).

These equations for DR, Vi, Ir and Ii assume the six levels are sampled simultaneously by the processor 80. If the six levels are not sampled simultaneously, the above equations must be modified to compensate for the resulting phase angle discrepancies (see numbered paragraph 41).

The calculation of apparent power is unique:

instantaneous power factor = $(Vr*Ir + Vi*Ii)/((Vr^2 + Vi^2)*(Ir^2 + Ii^2))^{0.5}$ (see numbered paragraph 49).

This equation is the form used by the processor 80 and the algorithm 140 to calculate a value of instantaneous power factor. The equation uses the levels of voltages and currents but does not directly use trigometric functions or phase angles. No conversion between Y and Delta configurations is needed (see numbered paragraph 50).

The processor also uses values of instantaneous power factor to detect a momentary power loss (MPL) condition. In step 250 of the MPL algorithm 150, the algorithm 140 is called to calculate consecutive instances of the values of instantaneous three-phase power factor at a predetermined sampling rate. As long as the instantaneous power factors are positive, an MPL condition does not exist. If the last six consecutive values of instantaneous three-phase power factor have been non-positive, then an MPL condition is detected as shown in step 280 and the processor commands the motor contactors to disconnect the power from the motor 60 (see numbered paragraph 53).

This method of calculating power factors is independent of source and load wye and delta configurations. The method is also independent of the configuration in which the voltage and current levels are measured. Time intensive sampling of the voltage and current levels is avoided by this method, and a processor with a fast clock and higher cost can therefore be avoided. Calculations of power factor can be used in a time critical function which is a detection that momentary power loss conditions and detection of surge conditions (see numbered paragraph 52).

To fully comply with the requirements of 37 C.F.R. 41.37(c)(1)(v), the claims on appeal as listed in VI. "Grounds of Rejection to be Review on Appeal" are listed with citations to the Specification.

1. In a three-phase power system, an apparatus for generating a data value representative of instantaneous three-phase power factor comprising:

a processor 80 for sampling voltage levels and current levels from power source lines of said three-phase power system (page 9, lines 14-15) to form a set of voltage and current levels (page 10, lines 12-20), said processor being responsive to said set of voltage and current levels to generate said data value representative of said instantaneous three-phase power factor (page 13, lines 17-20).

2. The apparatus of claim 1 wherein said sampling of said voltage levels and current levels from said power source lines of said three-phase power system to form said set of voltage and current levels is done simultaneously by said processor (page 11, lines 16-17).

3. The apparatus of claim 1 wherein said processor is responsive to a voltage level subset of said set of voltage and current levels to generate real and imaginary component data values representative of a voltage phasor as part of generating said data value representative of said instantaneous three-phase power factor (page 11, lines 1-15).

4. The apparatus of claim 3 wherein said voltage level subset comprises at least two of:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference (page 10, lines 12-21).

5. The apparatus of claim 4 wherein said voltage level subset comprises:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference (page 10, lines 12-21).

6. The apparatus of claim 3 wherein said voltage level subset comprises at least two of:

a first line voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines (page 10, lines 12-21).

7. The apparatus of claim 6 wherein said voltage level subset comprises:

a first line voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines (page 10, lines 12-21).

8. The apparatus of claim 1 wherein said processor is responsive to a current level subset of said set of voltage and current levels to generate real and imaginary component data values representative of a current phasor as part of generating said data value representative of said instantaneous three-phase power factor (page 11, lines 1-15).

9. The apparatus of claim 8 wherein said current level subset comprises at least any two of:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines (page 10, lines 12-21).

10. The apparatus of claim 9 wherein said current level subset comprises:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines (page 10, lines 12-21).

11. The apparatus of claim 8 wherein said current level subset comprises at least any two of:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines (page 10, lines 12-21).

12. The apparatus of claim 11 wherein said current level subset comprises:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines (page 10, lines 12-21).

13. The apparatus of claim 1 further comprising said processor sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate over a pre-determined time interval to generate a set of instantaneous three-phase power factor data values (page 13, lines 24-31).

14. The apparatus of claim 13 wherein the sampling rate is selected to distribute the sample locations in the line cycle period and to provide representation sampling of instantaneous power factor values (page 13, line 24- page 14, line 5).

15. (canceled)

16. The apparatus of claim 1 further comprising said processor sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate to continuously generate a corresponding plurality of instantaneous three-phase power factor data values (page 13, lines 24-31).

17. The apparatus of claim 16 further comprising said processor continuously checking if each of a pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive) (page 14, line 22 - page 15, line 8).

18. The apparatus of claim 17 wherein said processor declares a detection of a momentary power loss condition if each of said pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive) (page 14, line 22 - page 15, line 8).

19. The apparatus of claim 18 wherein said processor commands that a load of said three-phase power system be at least temporarily disconnected from said power source lines when said processor declares said detection of said momentary power loss condition (page 15, lines 8-12).

20. In a three-phase power system, a method for generating a data value representative of instantaneous three-phase power factor comprising:

sampling voltage levels and current levels from power source lines of said three-phase power system to form a set of voltage and current levels (page 10, lines 11-9); and

generating said data value representative of said instantaneous three-phase power factor in response to said set of voltage and current levels (page 13, lines 17-20).

21. The method of claim 20 wherein said sampling of said voltage levels and current levels from said power source lines of said three-phase power system to form said set of voltage and current levels is done simultaneously (page 11, lines 16-17).

22. The method of claim 20 further comprising generating real and imaginary component data values representative of a voltage phasor in response to a voltage level subset of said set of voltage and current levels as part of generating said data value representative of said instantaneous three-phase power factor (page 11, lines 4-15).

23. The method of claim 22 wherein said voltage level subset comprises at least any two of:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference (page 10, liens 12-21).

24. The method of claim 23 wherein said voltage level subset comprises:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference (page 10, liens 12-21).

25. The method of claim 22 wherein said voltage level subset comprises at least any two of:

a first voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines (page 10, liens 12-21).

26. The method of claim 25 wherein said voltage level subset comprises:

a first voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines (page 10, liens 12-21).

27. The method of claim 20 further comprising generating real and imaginary component data values representative of a current phasor in response to a current level subset of said set of voltage and current levels as part of generating said data value representative of said instantaneous three-phase power factor (page 11, lines 4-15).

28. The method of claim 27 wherein said current level subset comprises at least any two of:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines (page 10, lines 12-21).

29. The method of claim 28 wherein said current level subset comprises:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines (page 10, lines 12-21).

30. The method of claim 27 wherein said current level subset comprises at least any two of:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines (page 10, lines 12-21).

31. The method of claim 30 wherein said current level subset comprises:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines (page 10, lines 12-21).

32. The method of claim 20 further comprising sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate over a pre-determined time interval to generate a set of instantaneous three-phase power factor data values (page 13, lines 24-31).

33. The method of claim 32 wherein the sampling rate is selected to distribute the sample locations in the line cycle period and to provide representation sampling of instantaneous power factor values (page 13, line 24 - page 14, line 5).

34. (canceled)

35. The method of claim 20 further comprising sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate to continuously generate a corresponding plurality of instantaneous three-phase power factor data values (page 13, line 22 - page 15, line 8).

36. The method of claim 35 further comprising continuously checking if each of a pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive) (page 14, line 22 - page 15, line 8).

37. The method of claim 36 further comprising declaring a detection of a momentary power loss condition if each of said pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive) (page 14, line 22 - page 15, line 8).

38. The method of claim 37 further comprising commanding that a load of said three-phase power system be at least temporarily disconnected from said power source lines when said detection of said momentary power loss condition is declared (page 15, lines 8-12).

39. A method of calculating power factor comprising the steps of:

determining a set of three currents respectively associated with three motor phases (page 11, lines 1-2);

determining a set of three voltages respectively associated with three motor phases (page 11, lines 1-2);

calculating current phasors and voltage phasors from the set of currents and the set of voltages (page 11, lines 2-15); and

determining an instantaneous power factor from the calculated current and voltage phasors (page 12, line 1 - page 13, line 17).

40. The method of claim 39 including the further step of averaging the instantaneous power factor over a line cycle to determine an average power factor (page 14, lines 2-4).

41. An arrangement for calculating power factor comprising:

means for determining a set of currents respectively associated with three motor phases (page 11, lines 1-2);

means for determining a set of three voltages respectively associated with three motor phases (page 11, lines 1-2);

means for calculating current phasors and voltage phasors from the set of currents and set of voltages (page 11, lines 2-15); and

means for determining an instantaneous power factor from the calculated current and voltage phasors (page 12, line 1 - page 13, line 17).

42. (previously amended) The arrangement of claim 41 further including means for averaging the instantaneous power factor over a line cycle to determine an average power factor (page 14, line 2-4).

VI. Grounds of Rejection to be Reviewed on Appeal

A. Are claims 1 and 20 Novel and Patentable Under 35 U.S.C. Section 102(b) in View of U.S. Patent 5,521,482 to Lang et al.?

B. Are claims 2 and 21 Novel and Patentable Under 35 U.S.C. Section 102(b) in View of U.S. Patent 5,521,482 to Lang et al.?

C. Are claims 6, 7, 11, 12, 25, 26, 30 and 31 Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,673,196 to Hoffman et al.?

D. Are claims 13, 14, 16-19, 32, 33 and 35-38 Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.?

E. Are claims 17 and 36 Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.?

F. Are claims 13, 16, 32 and 35 Independently Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.?

G. Are claims 18 and 37 Independently Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 5,521,482 to Lang et al.; U.S. Patent 5,673,196 to Hoffman et al.; and U.S. Patent 5,434,738 to Kurszewski et al.?

H. Are claims 39 and 41 Independently Novel and Patentable Under 35 U.S.C. Section 102(b) in View of U.S. Patent 5,521,482 to Lang et al.?

I. Are claims 40 and 42 Independently Novel and Patentable Under 35 U.S.C. Section 103(a) in View of the Proposed Combination of U.S. Patent 4,421,482 to Lang et al. and U.S. Patent 5,229,713 to Bullock et al.?

VII. Argument

A. CLAIMS 1 AND 20 ARE NOVEL AND PATENTABLE IN VIEW OF U.S. PATENT 5,521,482 TO LANG ET AL.

Claims 1 and 20 stand rejected under 35 U.S.C. Section 102 in view of U.S. Patent 4,421,482 to Lang et al.

1. U.S. Patent 5,521,482 to Lang et al. Does Not Disclose Sampling Voltage Levels and Current Levels to Form a Set of Voltage and Current Levels

Lang et al. clearly states "each of the conditioned and digitized signals from each of the current probes 42, 44, 46 and from the three voltage probes 48, 50, 52 are individually analyzed and processed by the computer 12" (see Lang column 9, lines 19-23, emphasis added). The phase difference is individually determined for the each electrical phase per language in Lang et al. column 10, lines 7-10. Moreover the power factor for each electrical phase is determined individually (see Lang et al. column 10, lines 13-15).

Claim 1 and claim 20 specify voltage levels and current levels in the plural sense. These voltage and current levels are used to form a set of voltage and current levels, and the set of voltage levels used to generate a data value representative of instantaneous three-phase power factor. Since Lang et al. makes separate calculations for each phase, Lang et al. does not meet this requirement and claims 1 and 20 and their dependent claims are submitted to be novel and patentable.

B. CLAIMS 2 AND 20 ARE NOVEL AND PATENTABLE IN VIEW OF U.S. PATENT 5,521,482 TO LANG ET AL.

Claims 2 and 21 stand rejected under 35 U.S.C. Section 102 in view of U.S. Patent 5,521,482 to Lang et al.

1. Claims 2 and 21 Stand Rejected Under 35 U.S.C. Section 102 in View of Lang et al.

Claims 2 and 21, require that "sampling" of voltages and currents be done "simultaneously" to form a set of voltage levels and current levels and that this set be used to calculate instantaneous power factor.

2. Lang et al. Makes No Disclosures Regarding Simultaneous Sampling

In addition to the above noted deficiency in Lang et al., Lang et al. does not disclose simultaneous sampling of a set of such values. No such disclosure can be specifically identified in Lang et al.

3. Lang et al. Requires Phase Demodulation

Referencing Figure 4 of Lang et al., Lang et al. includes a "Phase Demodulation" block 402. By its nature, the Phase Demodulation Block 402 requires a series of measurements over time in order to accomplish modulation and cannot be considered 'simultaneous'. Voltage/Current Phase Difference Block 406 depends on Block 402 and thus requires demodulation over time. Power Factor Phase Block 408 in turn depends upon Block 406 and the phase difference calculated therein. This Figure 4 indicates that power factor as calculated by Lang et al. requires a series of measurements over time and that Lang et al. does not provide simultaneous sampling.

4. Lang et al. Consistently Makes Its Disclosures "As a Function of Time"

The sensing of current and voltage is disclosed throughout Lang et al. as a function of time (for example, column 3, line 30 and column 3, line 56) as is the sensing of voltage (column 3, line 32 for example) The sensed current and sensed voltage signals are specified to provide a phase modulated current signal as a function of time and a phase to modulated voltage signal as a function of time for more than one electrical phase

(see column 3, line 37-42). See also column 7, line 55; column 8, lines 38-39; column 9, line 25; column 9, lines 32-36; column 10, lines 5-7. This disclosure of measuring as a function of time indicates that simultaneous sampling does not occur.

5. Lang et al.'s Disclosures are in Terms of RMS

The disclosures of Lang et al. are also specified in terms of RMS (column 10, line 25 and column 11, line 4), RMS being an average value by definition and therefore further indicative that simultaneous sampling does not occur in Lang et al..

For all of these reasons, claims 2 and 21 are submitted to be novel and patentable in view of Lang et al.

C. CLAIMS 6, 7, 11, 12, 25, 26, 30 AND 31 ARE NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL. AND U.S. PATENT 5,673,196 TO HOFFMAN ET AL.

1. These Claims are Conceded to be Novel and Patentable in View of Lang et al.

Claims 6, 7, 11, 12 25, 26, 30 and 31 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,673,196 to Hoffman et al. In making the rejection, the Examiner concedes that Lang et al. does not specify that the processor is responsive to line current and voltage signals. Thus, these claims are conceded to be novel and patentable in view of Lang et al.

2. No Reason is Provided to Combine Lang et al. with Hoffman et al.

Lang et al. is directed to an improved method and apparatus for assessing the mechanical and electrical performance of an induction motor by deducing its various characterizing torques, horsepower and mechanical efficiency from its electrical signature exhibited during start-up (see Lang et al. column 1, lines 13-20). Hoffman et al. is directed to

apparatus and methods for metering vector electrical quantities for electrical power lines having multiple conducting paths (see Hoffman et al. column 1, lines 7-10). Thus, Lang et al. and Hoffman et al. are not particularly relevant to each other.

In order to make the combination proposed by the Examiner, some reason in Hoffman et al. or Lang et al. must be identified that would cause a person of ordinary skill in the art to make the proposed combination. No such suggestion has been identified and applicant submits that, in view of the failure of the Examiner to meet the burden to identify such suggestion, the proposed combination cannot be made.

Claims 6, 7, 11, 12, 25, 26, 30 and 31 are therefore submitted to be novel and patentable in view of the prior art of record.

D. CLAIMS 13, 14, 16-19, 32, 33 AND 35-38 ARE NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL.; U.S. PATENT 5,673,176 TO HOFFMAN ET AL.; AND U.S. PATENT 5,434,738 TO KURSZEWSKI ET AL.

1. These Claims are Conceded to be Novel and Patentable in view of the Combination of Lang et al. and Hoffman et al.

Claims 13, 14, 16-19, 32, 33 and 35-38 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al., U.S. Patent 5,673,196 to Hoffman et al. and U.S. Patent 5,434,738 to Kurszewski et al. In making the rejection, the Examiner concedes that the combination of Lang et al. and Hoffman et al. does not teach continuously generating a set of instantaneous three-phase power factor data values in order to check if a predetermined consecutive number of values are negative in order to declare detection of a momentary power loss condition and command that the load of the system be temporarily disconnected. Thus, these claims are conceded to be novel in view of the proposed combination of Lang et al. and Hoffman et al.

2. A Person of Ordinary Skill in the Art Would Not Combine Kurszewski et al. with Lang et al. and Hoffman et al.

Kurszewski et al. teaches away from the proposed combination and therefore a person of ordinary skill in the art would not make the combination proposed by the Examiner. At column 7, lines 33-34 of the Kurszewski et al., Kurszewski et al. specifically states "it is not necessary to actually calculate the magnitude of the power factor", actually teaching away from the power factor calculations of the present invention. Thus, a person of ordinary skill in the art would not make the proposed combination of Lang et al., Hoffman et al. and Kurszewski et al. to reach the claimed invention particularly where the Examiner conceded that the combination of Hoffman et al. and Lang et al. is insufficiently itself to reach the claimed invention and where Kurszewski et al. teaches away from power factor calculations.

3. There is No Reason to Make the Proposed Combination

There is no reason identified in Lang et al., Hoffman et al. and/or Kurszewski et al. to make the proposed combination. Without such reason, the combination would not be made, particularly in view of Kurzewski's teaching.

Applicant therefore submits that these claims are novel and patentable over the prior art of record.

E. CLAIMS 17 AND 36 ARE NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL.; U.S. PATENT 5,673,196 TO HOFFMAN ET AL. AND U.S. PATENT 5,434,738 TO KURSZEWSKI ET AL.

Claims 17 and 36 stand rejected under 35 U.S.C. Section 103 in view of the proposed combination of Lang et al., Hoffman et al. and Kurszewski et al.

1. Lang et al. Does Not Check to Determine if Each of the Determined Consecutive Numbers of Most Recent Values are Less Than or Equal to Zero

Claims 17 and 36 require continuously checking if each of a predetermined consecutive numbers of most recent data values of a corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero. Lang et al. does not disclose this requirement and applicant submits that, together with the other deficiencies of Lang et al. noted above, that these claims are independently novel and patentable in view of Long et al.

2. Neither Hoffman et al. Nor Kurszewski et al. Remedy the Deficiencies of Lang et al.

Neither Hoffman et al. nor Kurszewski et al. remedy the deficiencies of Lang et al. and neither reference teaches comparing consecutive instantaneous three-phase power factor data values to zero. Consequently, the combination of these references fails to disclose the claim requirements of claims 17 and 36.

3. There is No Suggestion in the References to Make the Proposed Combination or to Modify the Combination to Reach the Claimed Invention

All of the foregoing comments regarding the inadequacies of making this proposed combination are relevant but are not repeated for the sake of brevity.

Applicant also submits that there is no suggestion in any of these references to make the combination proposed by the Examiner or, once that combination has been made, to modify the combination to reach the requirements of claims 17 and 36. It is incumbent upon the Examiner to identify such suggestions and applicant submits that the Examiner has not met this burden.

Consequently, claim 17 and 36 are submitted to be novel and patentable over the prior art of record whether that prior art is taken individually or in combination.

F. CLAIMS 13, 16, 32 AND 35 ARE INDEPENDENTLY NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL.; U.S. PATENT 5,673,196 TO HOFFMAN ET AL.; AND U.S. PATENT 5,434,738 TO KURSZEWSKI ET AL.

Claims 13, 16, 32 and 35 stand rejected under 35 U.S.C. Section 103 in view of the proposed combination of Lang et al., Hoffman et al. and Kurszewski et al.

1. The References Do Not Disclose the Concept of Generating a Set or Plurality of Instantaneous Three-Phase Power Factor Data Values

These claims require sampling a plurality of sets of voltage and current levels at a predetermined sampling rate over a predetermined time interval to generate a set of instantaneous three-phase power factor data values. The prior art of record appears to generate its calculations on a phase by phase basis and does not disclose or suggest generating a set or plurality of instantaneous three-phase power factor data values.

2. These References Provide No Reason to Make or Modify the Proposed Combination

All of the foregoing comments regarding the inadequacies of making this proposed combination are relevant but are not repeated for the sake of brevity.

These claims do not make any disclosure of any reason to make the combination proposed by the Examiner or to modify the combination once made to reach the claimed invention. Applicant submits that absent such disclosure, the Examiner has not met his burden of proof.

Claims 13, 16, 32 and 35 are submitted to be independently patentable in view of Lang et al. in view of the concept of generating a set or plurality of instantaneous three phase power factor data values.

G. CLAIMS 18 AND 37 ARE INDEPENDENTLY NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL.; U.S. PATENT 5,673,196 TO HOFFMAN ET AL.; AND U.S. PATENT 5,434,738 TO KURSZEWSKI ET AL.

Claims 18 and 37 stand rejected under 35 U.S.C. Section 103 in view of the proposed combination of Lang et al., Hoffman et al. and Kurszewski et al. These claims require that a processor declare a detection of a momentary power loss condition if each of the predetermined consecutive number of most recent data values is less than or equal to zero.

It is submitted that the references of record do not disclose such a way of determining momentary power loss nor do they determine the requisite components necessary to make such declaration. As previously noted, Kurzsewski et al. makes no disclosures concerning the use of power factor, and specifically teaches away from making power factor calculations in its statement "it is not necessary to calculate the magnitude of a power factor" (Kurzsewski et al. column 7, lines 33, 34). In addition, the Examiner has conceded that a combination of Lang et al. and Hoffman et al. fail to disclose these claims. In view of this failure as well as the lack of suggestion in the references to make any or modify any combination which might result in the claimed invention, these claims are submitted to be independently novel and patentable.

Consequently, claims 18 and 37 are submitted to be independently novel and patentable due to their determination of a momentary power loss condition if each of those data values were less than or equal to zero.

H. CLAIMS 39 AND 41 ARE INDEPENDENTLY NOVEL AND PATENTABLE IN VIEW OF U.S. PATENT 5,521,482 TO LANG ET AL.

Claims 39 and 41 are rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,229,713 to Bullock et al.

These claims require determining a set of currents, determining a set of three voltages, calculating current phasors and voltage phasors from the set of currents and the set of voltages, and determining an instantaneous power factor from the calculated current and voltage phasors.

1. The Cited References Do Not Disclose Determining a Set of Currents and a Set of Voltages Respectively Associated with Three Motor Phases

The claim essentially requires that currents be determined from each the three motor phases and that three voltages be determined from each of the three motor phases as a set. It is submitted that neither Lang et al. nor Bullock et al. meets this requirements.

At best, the prior art can be characterized as calculating power factor from a current and a voltage, not from a set of such measurements.

The foregoing discussions regarding Lang et al. are relevant, particularly in view of Lang et al.'s individual calculations noted above. but are not repeated for the sake of brevity.

Bullock et al. is directed to a method of operating a meter, and makes no disclosures regarding the calculation of power factor as disclosed and claimed by the present invention.

The references fail to make disclosures regarding calculating phasors and power factor from sets of voltage and current measurements.

2. The Cited References Do Not Disclose Calculating Current Phasors and Voltage Phasors from the Set of Currents and the Set of Voltages

Since neither reference discloses determining sets of voltages and currents, neither reference can make any disclosures regarding calculating phasors from sets of either currents or voltages. Consequently, this claimed requirement is not met.

3. Use of Phasors as Claimed Does Not Disclose to Calculate an Instantaneous Power Factor

It is also submitted that the references do not disclose determining instantaneous power factor from the calculated current and voltage phasors where those phasors are determined from a set of three voltages associated with three motor phases and a set of currents associated with three motor phases.

4. There is No Reason to Make the Proposed Combination Nor to Modify the Proposed Combination if Made

It is incumbent upon the Examiner to identify a reason to make the combination proposed by the Examiner. Applicant submits that there is no reason evident from either Lang et al. or from Bullock et al. Therefore, the Examiner has not met his burden to indicate why a person of ordinary skill in the art would make the combination proposed by the Examiner.

Applicant submits that the combination does not disclose the invention of claimed 39 and 41 and that the combination would not be made by a person of ordinary skill in the art. Consequently, claim 39 and 41 are submitted to be novel and patentable in view of the prior art of record.

I. CLAIMS 40 AND 42 ARE INDEPENDENTLY NOVEL AND PATENTABLE IN VIEW OF THE PROPOSED COMBINATION OF U.S. PATENT 5,521,482 TO LANG ET AL. AND U.S. PATENT 5,229,713 TO BULLOCK ET AL.

Claims 40 and 42 stand rejected under 35 U.S.C. Section 103(a) in view of the proposed combination of Lang et al. and U.S. Patent 5,229,713 to Bullock et al.

1. Claims 40 and 42 Require an Average of Instantaneous

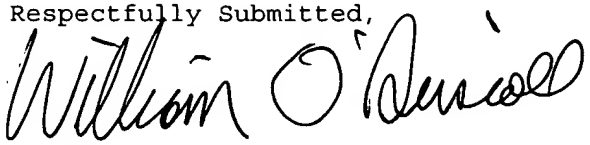
Claims 40 and 42 require averaging an instantaneous power factor of a line cycle to determine an average power factor. None of the cited references disclose this averaging concept, or suggest any combination or modification which might result in this averaging concept.

Claims 40 and 42 are therefore submitted to be independently novel and patentable due to their averaging concept.

J. SUMMARY

For all of the above recited reasons, the claims on file are submitted to be novel and patentable in view of the references of record.

Respectfully Submitted,



William O'Driscoll
Registration No. 33,294

Telephone Number: (608)787-2538

VIII. Claims Appendix

1. (original) In a three-phase power system, an apparatus for generating a data value representative of instantaneous three-phase power factor comprising:

a processor for sampling voltage levels and current levels from power source lines of said three-phase power system to form a set of voltage and current levels, said processor being responsive to said set of voltage and current levels to generate said data value representative of said instantaneous three-phase power factor.

2. (original) The apparatus of claim 1 wherein said sampling of said voltage levels and current levels from said power source lines of said three-phase power system to form said set of voltage and current levels is done simultaneously by said processor.

3. (original) The apparatus of claim 1 wherein said processor is responsive to a voltage level subset of said set of voltage and current levels to generate real and imaginary component data values representative of a voltage phasor as part of generating said data value representative of said instantaneous three-phase power factor.

4. (original) The apparatus of claim 3 wherein said voltage level subset comprises at least two of:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference.

5. (original) The apparatus of claim 4 wherein said voltage level subset comprises:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference.

6. (original) The apparatus of claim 3 wherein said voltage level subset comprises at least two of:

a first line voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines.

7. (original) The apparatus of claim 6 wherein said voltage level subset comprises:

a first line voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines.

8. (original) The apparatus of claim 1 wherein said processor is responsive to a current level subset of said set of voltage and current levels to generate real and imaginary component data values representative of a current phasor as part of generating said data value representative of said instantaneous three-phase power factor.

9. (original) The apparatus of claim 8 wherein said current level subset comprises at least any two of:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines.

10. (original) The apparatus of claim 9 wherein said current level subset comprises:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines.

11. (original) The apparatus of claim 8 wherein said current level subset comprises at least any two of:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines.

12. (original) The apparatus of claim 11 wherein said current level subset comprises:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines.

13. (original) The apparatus of claim 1 further comprising said processor sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate over a pre-determined time interval to generate a set of instantaneous three-phase power factor data values.

14. (original) The apparatus of claim 13 wherein the sampling rate is selected to distribute the sample locations in the line cycle period and to provide representation sampling of instantaneous power factor values.

15. (canceled)

16. (original) The apparatus of claim 1 further comprising said processor sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate to continuously generate a corresponding plurality of instantaneous three-phase power factor data values.

17. (original) The apparatus of claim 16 further comprising said processor continuously checking if each of a pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive).

18. (original) The apparatus of claim 17 wherein said processor declares a detection of a momentary power loss condition if each of said pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive).

19. (original) The apparatus of claim 18 wherein said processor commands that a load of said three-phase power system be at least temporarily disconnected from said power source lines when said processor declares said detection of said momentary power loss condition.

20. (original) In a three-phase power system, a method for generating a data value representative of instantaneous three-phase power factor comprising:

sampling voltage levels and current levels from power source lines of said three-phase power system to form a set of voltage and current levels; and

generating said data value representative of said instantaneous three-phase power factor in response to said set of voltage and current levels.

21. (original) The method of claim 20 wherein said sampling of said voltage levels and current levels from said power source lines of said three-phase power system to form said set of voltage and current levels is done simultaneously.

22. (original) The method of claim 20 further comprising generating real and imaginary component data values representative of a voltage phasor in response to a voltage level subset of said set of voltage and current levels as part of generating said data value representative of said instantaneous three-phase power factor.

23. (original) The method of claim 22 wherein said voltage level subset comprises at least any two of:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference.

24. (original) The method of claim 23 wherein said voltage level subset comprises:

a first phase voltage level sampled from a first source line of said power source lines relative to a common voltage reference;

a second phase voltage level sampled from a second source line of said power source lines relative to a common voltage reference; and

a third phase voltage level sampled from a third source line of said power source lines relative to a common voltage reference.

25. (original) The method of claim 22 wherein said voltage level subset comprises at least any two of:

a first voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines.

26. (original) The method of claim 25 wherein said voltage level subset comprises:

a first voltage level sampled from a first source line relative to a second source line of said power source lines;

a second line voltage level sampled from said second source line relative to a third source line of said power source lines; and

a third line voltage level sampled from said third source line relative to said first source line of said power source lines.

27. (original) The method of claim 20 further comprising generating real and imaginary component data values representative of a current phasor in response to a current level subset of said set of voltage and current levels as part of generating said data value representative of said instantaneous three-phase power factor.

28. (original) The method of claim 27 wherein said current level subset comprises at least any two of:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines.

29. (original) The method of claim 28 wherein said current level subset comprises:

a first phase current level sampled from a first source line of said power source lines;

a second phase current level sampled from a second source line of said power source lines; and

a third phase current level sampled from a third source line of said power source lines.

30. (original) The method of claim 27 wherein said current level subset comprises at least any two of:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines.

31. (original) The method of claim 30 wherein said current level subset comprises:

a first line current level sampled from a first source line of said power source lines;

a second line current level sampled from a second source line of said power source lines; and

a third line current level sampled from a third source line of said power source lines.

32. (original) The method of claim 20 further comprising sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate over a pre-determined time interval to generate a set of instantaneous three-phase power factor data values.

33. (original) The method of claim 32 wherein the sampling rate is selected to distribute the sample locations in the line cycle period and to provide representation sampling of instantaneous power factor values.

34. (canceled)

35. (original) The method of claim 20 further comprising sampling a plurality of sets of voltage and current levels at a pre-determined sampling rate to continuously generate a corresponding plurality of instantaneous three-phase power factor data values.

36. (original) The method of claim 35 further comprising continuously checking if each of a pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive).

37. (original) The method of claim 36 further comprising declaring a detection of a momentary power loss condition if each of said pre-determined, consecutive number of most recent data values of said corresponding plurality of instantaneous three-phase power factor data values is less than or equal to zero (non-positive).

38. (original) The method of claim 37 further comprising commanding that a load of said three-phase power system be at least temporarily disconnected from said power source lines when said detection of said momentary power loss condition is declared.

39. (previously amended) A method of calculating power factor comprising the steps of:

determining a set of three currents respectively associated with three motor phases;

determining a set of three voltages respectively associated with three motor phases;

calculating current phasors and voltage phasors from the set of currents and the set of voltages; and

determining an instantaneous power factor from the calculated current and voltage phasors.

40. (previously amended) The method of claim 39 including the further step of averaging the instantaneous power factor over a line cycle to determine an average power factor.

41. (previously amended) An arrangement for calculating power factor comprising:

means for determining a set of currents respectively associated with three motor phases;

means for determining a set of three voltages respectively associated with three motor phases;

means for calculating current phasors and voltage phasors from the set of currents and set of voltages; and

means for determining an instantaneous power factor from the calculated current and voltage phasors.

42. (previously amended) The arrangement of claim 41 further including means for averaging the instantaneous power factor over a line cycle to determine an average power factor.

IX. Evidence Appendix

A. Record of Evidence Entered by Examiner

B. Specification

C. Drawings

D. U.S. Patent 5,521,482 to Lang et al.

E. U.S. Patent 5,673,196 to Hoffman et al.

F. U.S. Patent 5,434,738 to Kurszewski et al.

G. U.S. Patent 5,229,713 to Bullock et al.

Appendix A

Record of Evidence

Record of Evidence Entered by the Examiner

The Drawing and Specification were accepted by the Patent Office as a part of the application as filed.

U.S. Patent 5,673,196 to Hoffman et al. and U.S. Patent 5,434,738 to Kurszewski et al. were cited by the Examiner on PTO Form 892 in the list of references cited in the Office Action mailed October 1, 2004.

U.S. Patent 5,521,482 to Lang et al. and U.S. Patent 5,229,713 to Bullock et al. were cited by the Examiner on PTO From 892 in connection with the Office Action mailed May 31, 2005.

DETERMINATION AND APPLICATIONS OF THREE-PHASE POWER FACTOR

INVENTORS

Joel C. VanderZee
Michael W. Murry
Richard L. Vogel
Matthew A. Shepeck

BACKGROUND OF THE INVENTION

This disclosed embodiment relates to a three-phase power system such as, for example, a large commercial chiller. More particularly, this disclosed embodiment relates to determining three-phase power factor of a three-phase power system under load and using this three-phase power factor to protect the system from damage caused by such phenomenon as momentary power loss conditions.

In large commercial chillers, three-phase is the power of choice. Three-phase power systems consist of three alternating sources nominally spaced 120 degrees with respect to each other. The spatial separation of these sources set up a cyclic pattern that, when applied to a specific load, sets up a rotating magnetic field. This rotating magnetic field is ideal for allowing motors to turn successfully by converting electrical energy to mechanical energy. In commercial chillers, this mechanical energy is used to turn a refrigerant compressor, one of the critical stages in the refrigerant cycle. Although disclosed in terms of a commercial chiller, the present invention is intended to encompass the calculation of power factor in other applications.

Another type of power source is single-phase. In a single-phase power system, power is delivered to a load via a single alternating source. Even though the source is alternating, it is alternating within itself only and has no point of reference upon which a rotating magnetic field may result. If single-

phase power is used to energize motors, a rotating magnetic field needs to be artificially created locally to the motor, usually with a capacitor. Single-phase motors tend to be small in horsepower and have a large ratio of line current to horsepower. Three-phase power has the added advantage of delivering its energy through three sources instead of just one, resulting in smaller wire gauges to deliver the same amount of energy.

Working with three-phase systems presents issues not found in single-phase systems. In single-phase systems, there is a single source voltage and a single current that result when this source voltage is applied to a load. From measuring these two parameters, power factor can be calculated as:

$$\text{Power Factor} = \cos \Phi$$

Where Φ is the phase angle in which the current lags the voltage.

In working with three-phase systems, the determination of power factor is not a straight-forward calculation involving single entities of current and voltage phase angle. In three-phase systems, three sets of voltages and currents are all interacting with each other. If the three-phase system is symmetrical, that is, if all voltage sources are at exactly the same level and are exactly 120 degrees spatially apart, and the load each source sees is exactly the same, then the angle between the current and voltage of any particular phase of the load may be used to determine the three-phase power factor as:

$$\text{Three-Phase Power Factor} = \cos \Phi_p$$

Where Φ_p is the phase angle in which the current lags the voltage of the same configuration, i.e. both current and voltage measurements are taken in-the-delta of the motor.

However, sources of three-phase power systems are rarely balanced (i.e. the levels of the line-to-line voltages are equal, $V_{ab}=V_{bc}=V_{ca,}$ as seen by the load) nor is the load itself balanced between the three phases. There is no one angle between a voltage and a current that will indicate true three-phase power factor. In addition, Φ_p is the angle the current lags the voltage for currents and voltages measured in the same configuration. These are, for example, the currents and voltages across the load phase itself (i.e. delta currents and voltages). They also could be the currents and voltages of the source lines (i.e. wye currents and voltages). Typical control modules measure line currents and line-to-line voltages which, since they are not in the same configuration, have a 30 degree offset in the phase angle even if the load is a pure resistor. Here, the true three-phase power factor is unity (the true power factor angle is zero).

Previous designs have attempted to determine three-phase power factor by using one line current and one line-to-line voltage, accounting for the 30 degree difference. This method is only valid for ideally balanced sources and loads, which is rare in reality. The advantage of this method is that it is simple to implement and takes very little computing resources of a processor, memory, and processing power. An inexpensive processor could be used with this method. However, errors in power factor can be as great as 20% under normal unbalanced conditions. This large error gives the customer a false reading regarding what power factor the chiller is performing at, and limits other functions using power factor in their calculations. These other functions include determination of power consumption, surge conditions, and momentary power loss conditions.

True three-phase power factor calculations that are insensitive to the balance of load and source have been accomplished using a high-end processor capable of performing multiple trigonometric functions and digital signal processing. This processor is relatively expensive.

Momentary power losses (MPLs) are short durations of interruptions of the power being supplied to a load such as a motor. These interruptions may be the complete loss of all three phases of incoming power, the loss of one or two phases, or a dip in one, two, or all three phases. These interruptions may be very destructive to the rotating devices being powered. The devices include the motors themselves and/or their loads such as, for example, compressors. The destructiveness of the interruption is dependent on the type of motor and load and the nature and duration of the interruption. For small inertia loads, the motor/load decelerates and accelerates with the interruption with little impact on the reliability of the electromechanical system. For larger inertia motor/loads, the reclosure torques and currents are of a very large level for a longer period of time and impact the reliability of the motor and load. Transient currents may be as high as twelve times full load amps and transient torques may be as high as twelve times full load torque.

Reclosing into momentary power losses may result in large transient torques that could damage motor stator windings, motor shafts, impeller or shaft keyways, the impellers themselves, starter contactors, and branch circuit components. Momentary power losses may also cause the electronic controls to drop out unexpectedly and keep the system off until an operator gets involved. This could mean significant downtime for the system, resulting in a dissatisfied customer.

Momentary power losses may be caused by fault clearing devices being activated as the result of the forces of nature such as lighting strikes or animals coming into contact with the power lines. These interruptions may also be caused by power switching gear where a section of the power supply is moved from one power source to another.

Trying to detect momentary power loss and/or surges based on a single phase voltage and current of a three-phase power system can result in falsely detecting a momentary power loss condition or not detecting a true momentary power loss condition at all.

U.S. Patent 4,751,653 to Junk et al. is directed to a microprocessor based fault detector for identifying phase reversal, phase loss, and power loss in three-phase circuits. U.S. Patent 4,802,053 to Wojtak et al. is directed to a system for sensing the phase of a three-phase AC system and detecting phase reversal, under voltage, and phase unbalance. U.S. Patent 5,058,031 to Swanson et al. is directed to a method of protecting the compressor motor of a refrigeration system using a multi-phase AC power source. U.S. Patent 5,184,063 to Eisenhauer is directed to a three-phase reversal detection and correction system. U.S. Patent 5,200,682 to Kim et al. is directed to motor current phase delay compensating method and apparatus.

An approach to generating three-phase power factor directly and simply with an inexpensive set up and without having to convert between wye and delta configurations and without having to employ trigonometric calculations or having to measure phase, is desired. It is also desired to use three-phase power factor to protect three-phase power systems and their loads from damage.

BRIEF SUMMARY OF THE INVENTION

One aspect of the disclosed embodiment is a three-phase power system capable of sourcing power to a motor that drives a load such as, for example, the compressor of a chiller. The system sources three-phase power to a motor by applying three lines of voltage and current to the motor. Apparent power from a source has components of real power, reactive power, and distortion power. Real power is the power supplied by the source and dissipated by the load. Reactive power is a measure of the energy exchanged between the source and the load without being dissipated. Distortion power is that portion of the apparent power that cannot be used by the load due to distortions in the waveforms of the voltage and current. Power factor is the ratio of real power to apparent power and is, therefore, that fraction of the apparent power actually dissipated by the load. Power factor is also expressed as the cosine of the phase angle by which the current lags the voltage. In a three-phase power system, all three voltages and currents must be considered when determining a meaningful power factor.

Apparatus for determining instantaneous three-phase power factor and true three-phase power factor is provided. "True" means representative of the effective load the power is being sourced to over a line cycle. "Instantaneous" means representative of the load the power is being sourced to at a specific point in time. This apparatus includes a processor that monitors voltage levels and current levels from the source power lines of the three-phase power system. These voltage and current levels are sampled at a pre-determined rate and are used to calculate the power factors.

Another aspect of the disclosed embodiment is an apparatus for detecting momentary power loss conditions and other conditions with respect to normal operation. This apparatus includes the processor described above to process the three-phase power factor in order to detect these conditions. This allows the processor to react to the system to prevent damage to the motor and/or load of the system by these conditions.

A method for determining instantaneous three-phase power factor and true three-phase power factor is provided. "True" means representative of the effective load the power is being sourced to over a line cycle. "Instantaneous" means representative of the load the power is being sourced to at a specific point in time. This method includes monitoring voltage levels and current levels from the source power lines of the three-phase power system. These voltage and current levels are sampled at a pre-determined rate and are used to calculate the power factors.

Another aspect of the disclosed embodiment is a method for detecting momentary power loss conditions and other conditions with respect to normal operation. This method includes processing the three-phase power factors in order to detect these conditions. The method is able to react to the detection of these conditions to prevent damage to the motor and/or load of the system by these conditions.

The present invention provides a method of calculating power factor. The method comprises the steps of: determining three sets of currents respectively associated with three motor phases; determining three sets of voltages respectively associated with three motor phases; calculating current phasors and voltage phasors from the sets of currents and sets of voltages; and determining an instantaneous power factor from the calculated current and voltage phasors.

The present invention further provides an arrangement for calculating power factor. The arrangement comprises apparatus determining the magnitude of three sets of currents respectively associated with three motor phases; apparatus determining the magnitude of three sets of voltages respectively associated with three motor phases; apparatus calculating current phasors and voltage phasors from the sets of currents and sets of voltages; and apparatus determining an instantaneous power factor from the calculated current and voltage phasors.

By using the foregoing techniques, a simple, cost-effective approach to monitor the lines of a three-phase power system, calculate three-phase power factors, detect conditions which can cause damage to the system, and prevent such damage from occurring is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram of a three-phase power system made in accordance with the disclosed embodiment, particularly showing the processor that samples the voltage and current levels.

Figure 2 is a diagram of the traditional wye and delta configurations that the three-phase source and load can have in the three-phase power system of Figure 1.

Figure 3 is a modified schematic block diagram of the three-phase power system shown in Figure 1, particularly illustrating certain aspects of the processor including the digitization of the voltage and current levels and algorithms of the disclosed embodiment.

Figure 4 is a flowchart of the momentary power loss algorithm illustrated in Figure 3.

DETAILED DESCRIPTION OF THE INVENTION

The features of one embodiment enable a simple, low cost apparatus and method for determining three-phase power factor in a three-phase power system under load. This power factor is then used to detect momentary power loss conditions and other adverse conditions to allow action to be taken in order to protect the motor and load of the three-phase power system from damage when these conditions occur. This is accomplished by using a low-cost processor to sample voltage and current levels from the source lines of the three-phase power system and to perform subsequent calculations of power factor and detection of adverse conditions from these voltage and current levels.

Figure 1 is a schematic block diagram of a three-phase power system 10 made in accordance with the disclosed embodiment. A three-phase source 20 provides three-phase power over source lines 30, 40, and 50 to a three-phase motor 60 that drives a load 70. A processor 80 is configured to sample voltage levels and current levels from the source lines 30, 40, and 50.

Figure 2 shows the traditional delta configuration 90 and wye configuration 100 of how the source 20 and motor 60 can be configured in a three-phase power system 10. The disclosed embodiment is independent of these configurations and the various combinations thereof.

Figure 3 illustrates more detail of the disclosed embodiment including digitizers 110 and 120 of processor 80 for digitizing the voltage and current levels, and motor contactors 130 for connecting and disconnecting the motor 60 from the source lines 30, 40, and 50. The processor 80 also employs several software algorithms. These comprise a three-phase power factor algorithm 140, a momentary power loss (MPL) algorithm 150, and a surge algorithm 160.

The three-phase source 20 is electrically connected to the motor contactors 130 over the source lines 30, 40, and 50. The motor contactors 130 are electrically connected to the three-phase motor 60 over a contactor/motor interface 170 to provide three-phase power to the motor 60. The voltage digitizer 110 in the processor 80 is electrically connected to the source lines 30, 40, and 50 over voltage sampling interfaces 180, 190, and 200 to sample voltage levels. The current digitizer 120 in the processor 80 is electrically connected to the source lines 30, 40, and 50 over current sampling interfaces 210, 220, and 230 to sample current levels. The processor 80 is electrically connected to the motor contactors 130 through a processor/contactor interface 240.

To determine a value of three-phase power factor, the positive and negative levels of voltages and currents are measured from the source lines 30, 40, and 50 by the processor 80, maintaining the positive and negative signs of the measured levels. The measurements may be taken in various combinations of phase and/or line voltage levels and current levels (see Figure 2) such as:

first combination:	Vab, Vbc, Vca, Ia, Ib, Ic
second combination:	Va, Vb, Vc, Iab, Ibc, Ica
third combination:	Vab, Vbc, Vca, Iab, Ibc, Ica
fourth combination:	Va, Vb, Vc, Ia, Ib, Ic

where a, b, and c refer to the three source lines 30, 40, and 50 respectively. For example, Va is the phase voltage level on source line a with respect to a voltage reference. Vab is the line voltage levels between source lines a and b.

The three voltage levels and three current levels are sampled and digitized by the processor 80 and used to calculate values of a voltage phasor and values of a current phasor based on the expected geometric arrangement of the magnetic fields produced by the three phases. The values of real components (Vr and Ir) and the values of imaginary components (Vi and Ii) of the phasors are given by the following equations based on the 120° separation of the three phases:

If Vab, Vbc, and Vca are used:

$$Vr=3^{0.5}*0.5*Vbc \quad \text{and} \quad Vi=0.5*(Vab-Vca)$$

If Va, Vb, and Vc are used:

$$Vr=3^{0.5}*0.5*(Vb-Vc) \quad \text{and} \quad Vi=Va-0.5*(Vb+Vc)$$

If Ia, Ib, and Ic are used :

$$Ir=3^{0.5}*(Ib-Ic)/3 \quad \text{and} \quad Ii=Ia$$

If Iab, Ibc, and Ica are used:

$$Ir=3^{0.5}*(2*Ibc-Ica-Iab)/3 \quad \text{and} \quad Ii=Iab-Ica$$

These equations for Vr, Vi, Ir, and Ii assume the six levels are sampled simultaneously by the processor 80. If the six levels are not sampled simultaneously, the above equations must be modified to compensate for the resulting phase angle discrepancies. Also, for the line-to-line voltage levels and the line current levels, only any two need to be sampled by the processor 80. The third can be calculated from the other two by the processor 80. Additionally, a person of ordinary skill in the art will recognize that other equations may be used by adjusting the correspondence between phasor coordinates and three-phase coordinates.

The value of instantaneous power factor is calculated by the processor 80 using the algorithm 140 as

instantaneous power factor = cos Φ

where Φ is the spatial or geometric angle by which the current lags the voltage or the value of instantaneous power factor is calculated as

instantaneous power factor = cos(angle of the voltage phasor – angle of the current phasor).

$$= \cos(\theta_V - \theta_I)$$

In other words,

power factor = power/apparent power

power = V • I

apparent power = $|V| \cdot |I|$

$$= (V_r^2 + V_1^2)^{0.5} \cdot (I_r^2 + I_i^2)^{0.5}$$

$$= [V_r^2 + V_1^2) \cdot (I_r^I + I_i^2)]^{0.5}$$

The calculation of power is well-known by various calculations but the present invention's calculation of apparent power is unique.

Since,

$$\cos(\theta_V - \theta_I) = \cos(\theta_V) \cdot \cos(\theta_I) + \sin(\theta_V) \cdot \sin(\theta_I)$$

and

$$\cos(\theta_V) = \frac{V_r}{(V_r^2 + V_i^2)^{0.5}}$$

$$\sin(\theta_V) = \frac{V_i}{(V_r^2 + V_i^2)^{0.5}}$$

$$\cos(\theta_I) = \frac{I_r}{(I_r^2 + I_i^2)^{0.5}}$$

$$\sin(\theta_I) = \frac{I_i}{(I_r^2 + I_i^2)^{0.5}}$$

then by substitution

$$\text{instantaneous power factor} = (Vr*Ir + Vi*Ii)/((Vr^2 + Vi^2)*(Ir^2 + Ii^2))^{0.5}$$

This equation is the form used by the processor 80 and the algorithm 140 to calculate a value of instantaneous power factor. This equation uses the levels of the voltages and currents and does not directly use trigonometric functions or phase angles. No conversion between wye and delta configurations is needed.

To calculate a value of true three-phase power factor, the processor 80 samples and calculates multiple instances of values of instantaneous power factor at a pre-determined sampling rate over a pre-determined time interval (such as about but preferably not equal to a line cycle) of the three-phase power system. It is preferable that sampling rate not be equal to a line cycle so that sample locations in a line cycle are distributed in relation to a line cycle period but it is also preferable that the interval over which the samples are averaged is an exact multiple of the line cycles both for 50 Hz and 60 Hz. This provides a representative sampling of the instantaneous power factor. In one embodiment of the invention, this pre-determined sampling rate is every

2.5 msec. A line cycle is typically 20 msec or 16.67 msec corresponding to 50 Hz or 60 Hz source power respectively. The algorithm 140 then averages these values of instantaneous power factor to obtain a value of true three-phase power factor.

This value of true three-phase power factor represents the effective power factor of the load the power is being sourced to and has improved insensitivity to any imbalances of the source, line, or load. This method of calculating power factor is independent of source and load wye and delta configurations. This method is also independent of the configuration in which the voltage and current levels are measured. For example, they may be measured inside or outside a delta motor with the same results. Time intensive sampling of the voltage and current levels is avoided with this method. A processor with a fast clock and higher cost can, therefore, be avoided. These calculations of power factor are highly accurate to give the customer a true sense of the operating point of the system. These calculations of power factor can be used in time critical functions such as detection of momentary power loss (MPL) conditions and detection of surge conditions. With this implementation, expensive instrument grade power factor meters can be avoided. The same simple components and processor capability that are used for normal operation of, for example, a chiller motor can be used for determining power factor with this method.

Figure 4 illustrates how the processor 80 uses values of instantaneous power factor to detect a momentary loss of power (MPL) condition using the MPL algorithm 150. The three-phase power system is continuously monitored for an MPL condition. In step 250 of the MPL algorithm 150, the algorithm 140 is called to calculate consecutive instances of values of instantaneous three-phase power factor at a pre-determined sampling rate. In one

embodiment of the invention, this sampling rate is every 7.5 msec. In step 260 the values of instantaneous three-phase power factor are checked to determine if they are positive (numerically greater than zero). As long as the instantaneous power factors are positive, an MPL condition does not exist. In step 270, the algorithm 150 checks to see if the last six consecutive values of instantaneous three-phase power factors have been non-positive (numerically less than or equal to zero). If this is the case, then an MPL condition is detected as shown in step 280. The processor 80 then commands the motor contactors 130 to disconnect power from the motor 60. This will prevent damage from occurring to the motor 60 and/or load 70 due to the MPL condition. A pre-determined time interval elapses before the processor 80 attempts to re-connect source power to the motor 60.

Using power factor to determine an MPL condition is beneficial because the power factor represents the true state of the motor 60 at any point in time. This method is very responsive to power line anomalies, allowing the controls to obtain accurate information quickly. This method is also insensitive to DC offsets and non-symmetry of reclosure currents. It is also less sensitive to voltage and current unbalance conditions.

While the invention is described in connection with one embodiment, it will be understood that the invention is not limited to that one embodiment. On the contrary, the invention covers all alternatives, modifications, and equivalents within the spirit and scope of the appended claims.

For example, some possible alternatives might include the following described below. The voltage and current levels may not be sampled at the same time. The up to six inputs could be sampled and stored one at a time with a standard analog-to-digital converter that is subsequently read by the processor, or sampled in some other combination.

As another alternative, the three-phase power system may be monitored non-continuously for an MPL condition instead of continuously. For example, monitoring for an MPL condition may be initiated only when some other condition is detected first, such as, for example, a surge condition.

As a further alternative, the various algorithms may be combined in various ways or separated in various ways depending on the exact software implementation desired.

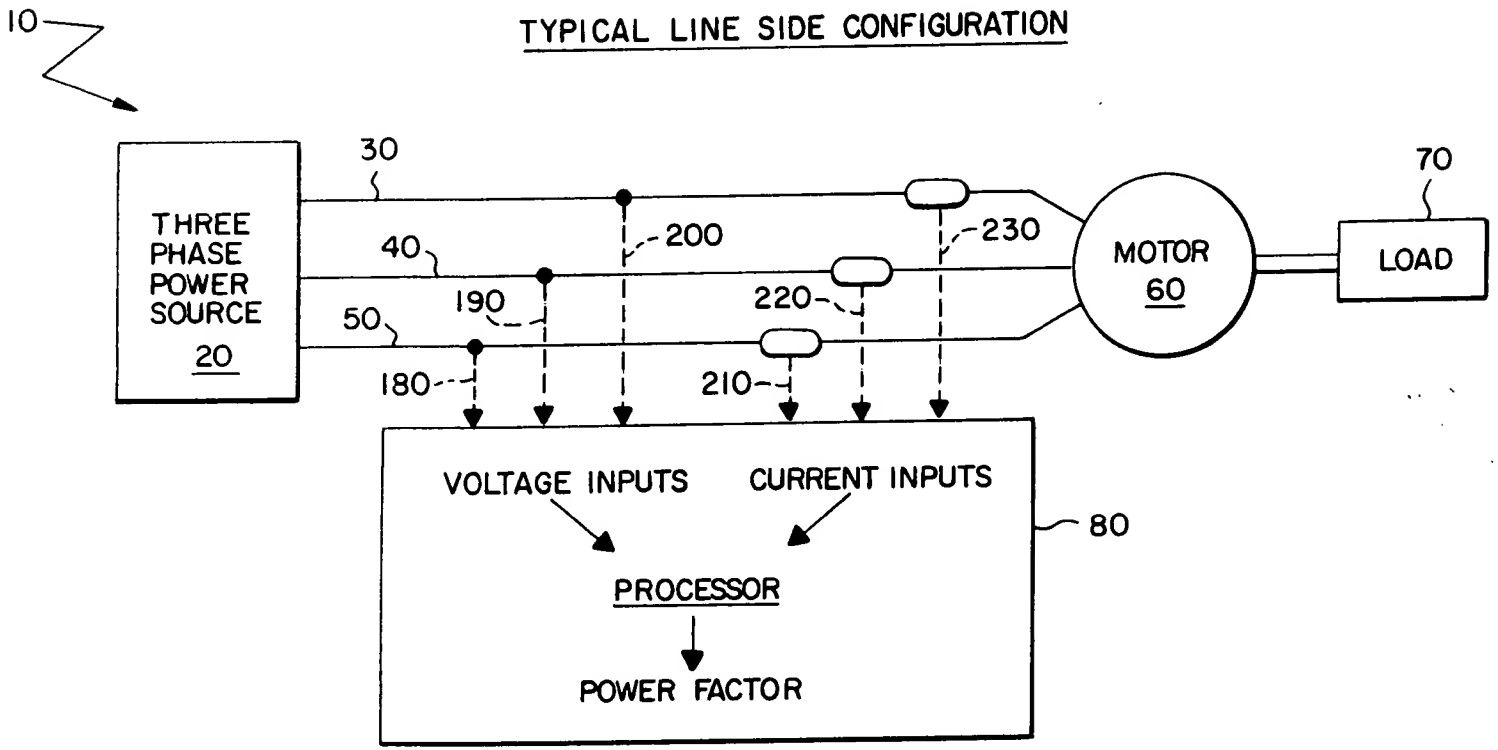

10
TYPICAL LINE SIDE CONFIGURATION
THREE PHASE POWER SOURCE 20
30
40
50
200
190
180
210
220
230
MOTOR 60
70
LOAD
VOLTAGE INPUTS
CURRENT INPUTS
80
PROCESSOR
POWER FACTOR

FIG. 1

FIG. 2

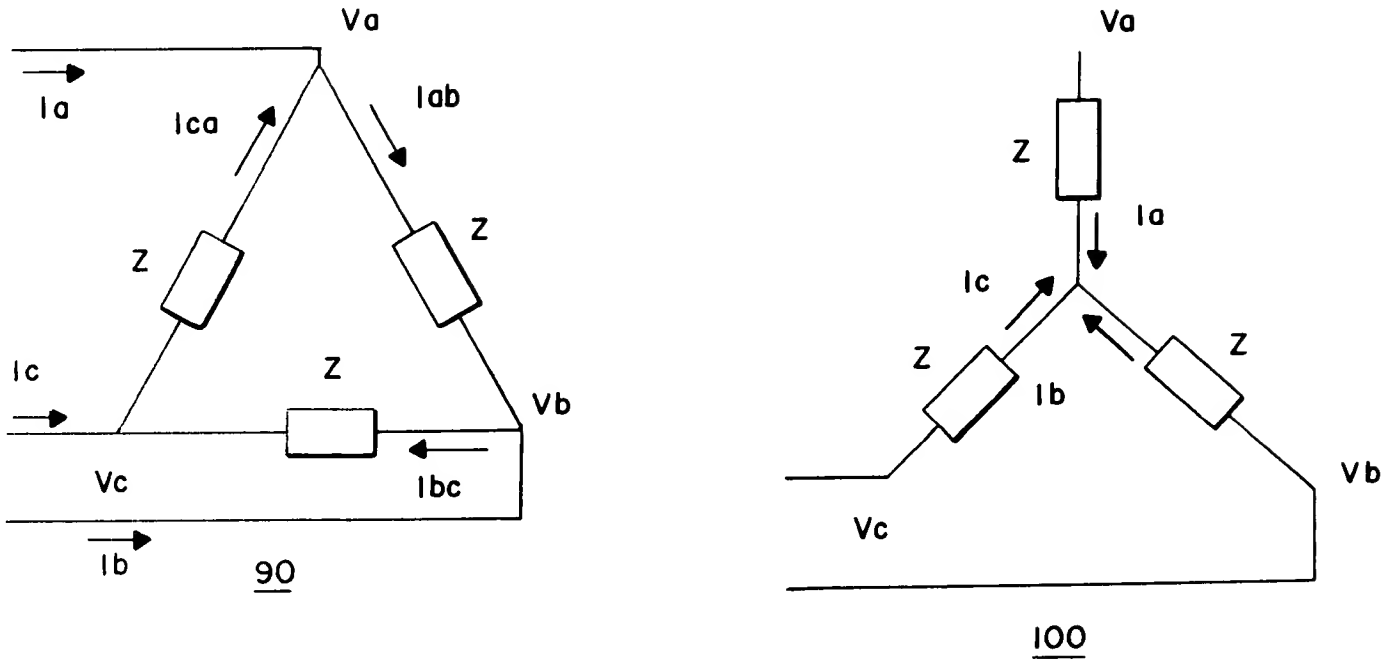
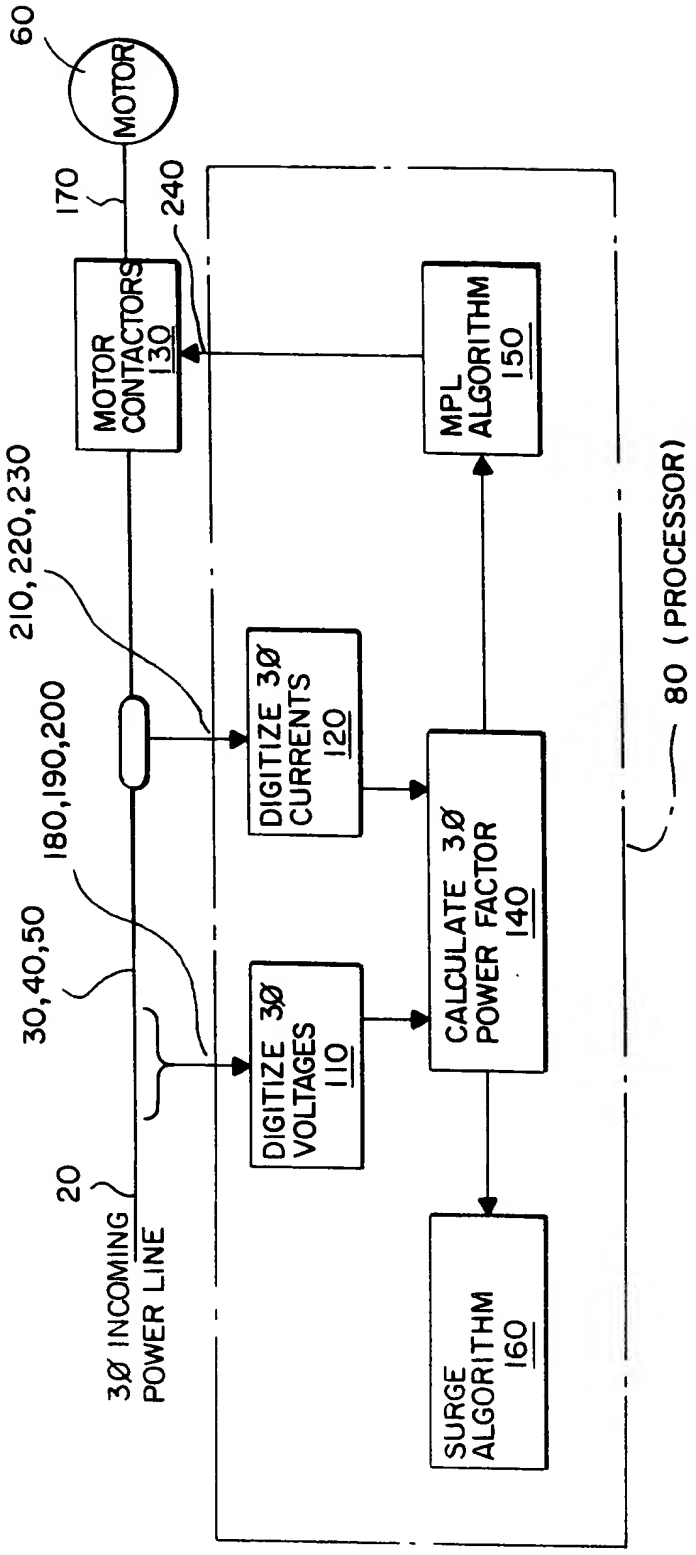


FIG 3


60
MOTOR
170
240
MOTOR CONTACTORS 130
MPL ALGORITHM 150
210, 220, 230
180, 190, 200
DIGITIZE 3Ø CURRENTS 120
30, 40, 50
DIGITIZE 3Ø VOLTAGES 110
CALCULATE 3Ø POWER FACTOR 140
20
3Ø INCOMING POWER LINE
SURGE ALGORITHM 160
80 (PROCESSOR)

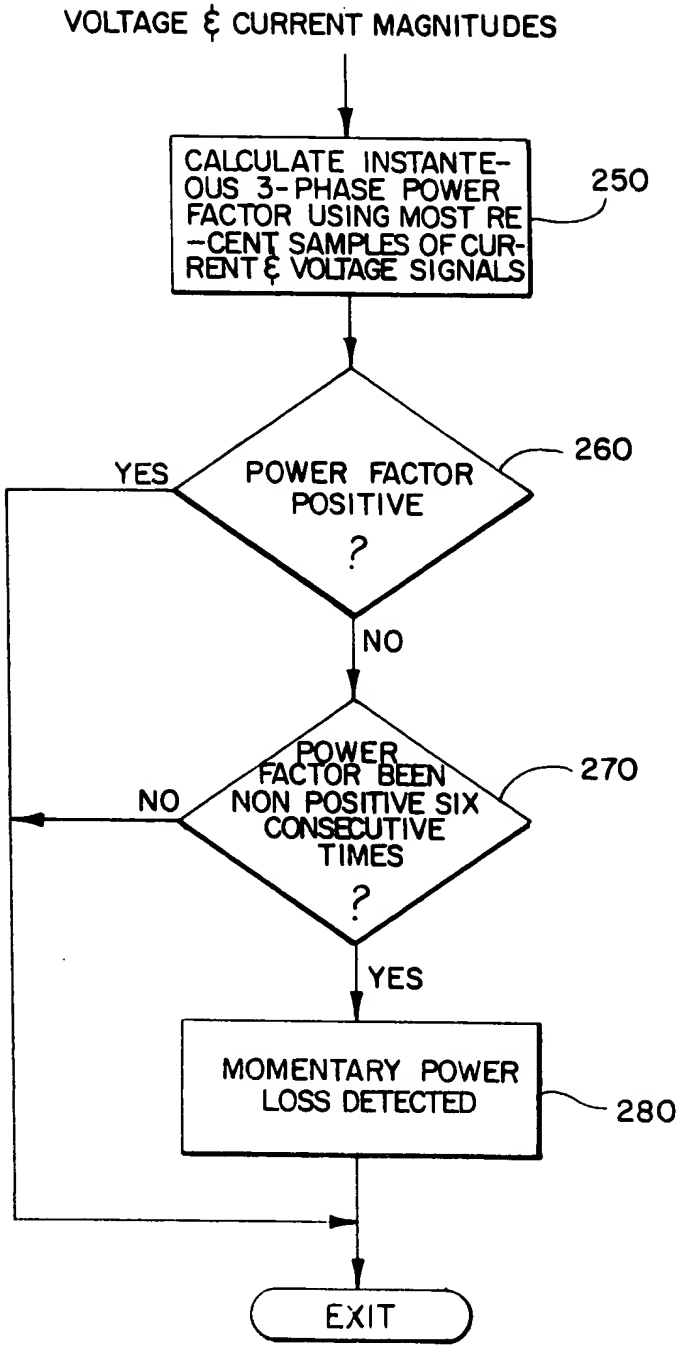

VOLTAGE & CURRENT MAGNITUDES
CALCULATE INSTANTE-OUS 3-PHASE POWER FACTOR USING MOST RE-CENT SAMPLES OF CUR-RENT & VOLTAGE SIGNALS
250
POWER FACTOR POSITIVE ?
260
YES
NO
POWER FACTOR BEEN NON POSITIVE SIX CONSECUTIVE TIMES ?
270
NO
YES
MOMENTARY POWER LOSS DETECTED
280
EXIT

FIG. 4